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SHORT COMMUNICATION

Validation of an activity monitor during sleep in patients with chronic respiratory disorders

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Summary
Introduction: Objective of this study was to validate an activity monitor (DynaPort MoveMonitor [MM], McRoberts, The Hague, The Netherlands) against night-vision video analysis during sleep.
Methods: Twenty patients (65 ± 11 years old, mean body-mass-index: 27 ± 6 kg/m^2) with different chronic lung diseases were recruited to participate in this validation study. Patients performed a polysomnography measurement during one single night while wearing the MM. The activity monitor data of the MM were then validated against the analysis of the night-vision video by an independent investigator. In total, four different lying positions (supine, left, right and prone), sitting upright, out of bed as well as large, medium, small and sitting transitions were classified.
Results: A mean duration of 7.6 ± 0.9 h per night of video and MM classification was available for analysis. In total, 702 different postures were registered on the video from which 678 postures (96.6%) were detected correctly by the MM compared to the video classification. These results yielded a total degree of sensitivity of 93.9% and specificity 94.9% in detecting postures during the night. In total, 682 transitions (394 small, 189 medium, 15 large and 84 sitting transitions) were detected of which 482 were also detected by the MM. The MM detected 70% of the

Abbreviationlist: COPD, chronic obstructive pulmonary disease; MM, MoveMonitor; NPV, negative predictive values; OOB, out of bed; PPV, positive predictive values.

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transitions correctly (51.0% small, 97.4% medium, 100% large and 97.6% sitting transitions).
Conclusion: The MM is an activity monitor showing a high degree of sensitivity and specificity to detect different nocturnal postures as well as medium and large sized transitions in patients with chronic respiratory disorders.

Introduction

Patients with chronic respiratory diseases report a high prevalence of sleep-related disturbances and poor sleep quality which is associated with a lower quality of life, frequent exacerbations and increased mortality [1,2]. Beside the standard measurement method of polysomnography used in sleep labs [3] an activity monitor could also provide relevant information on sleep quality by assessing physical movements during nighttime. Nocturnal activity monitoring could comprise the future potential (with later to be investigated parameters) to gain a quick insight into the sleep quality (maybe in addition to sleep questionnaires) in an ambulatory or even home-based fashion. This information might help to better select which patient should be measured by polysomnography to get a deep analysis of potential sleep disorders. This might help sleep labs to work more efficiently. Therefore, in a first step valid activity monitors are needed to quantify nocturnal postures and transitions. Aim of this study was to evaluate the validity of the DynaPort MoveMonitor (MM, McRoberts, The Hague, The Netherlands) against night-vision video analysis during nighttime for assessing different postures and transitions.

Methods

Twenty patients were recruited during an inpatient pulmonary rehabilitation program. Study subjects were 65 $\pm$ 11 years old, had a mean body-mass-index of 27 $\pm$ 6 kg/m^2 and suffered from different chronic respiratory disorders (COPD: n = 13, interstitial lung disease: n = 3, bronchial cancer: n = 2, obstructive sleep apnea syndrome: n = 2, post lung transplantation due to COPD: n = 2).

After giving written informed consent patients were asked to wear the MM for one single night while a night-vision video camera fixed at the ceiling was recording their nocturnal activities. The MM is a 55 g light small device that is worn around the waist using an elastic belt strap. It is well validated for daytime activity monitoring in patients with chronic lung diseases [4,5]. Part of the polysomnography measurement is a night-vision videotaping of the sleeping person which was used for video analysis to register postures and transitions. To synchronize the clock of the video recording and the activity recording of the MM device a knock on the device in sight of the camera was used as reference point for synchronization. The day after the night measurement an independent investigator watched the night-vision video and recorded time point and duration of different events using video analysis software (EUDICO Linguistic Annotator, version 4.6.1, Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands). In total, four different lying positions (in rotation of the longitudinal axis from perfect supine position: supine [-25°/$335^\circ - 25^\circ$], left [$25^\circ - 155^\circ$], right [$205^\circ - 335^\circ$], prone [$155^\circ - 205^\circ$]), sitting upright ($\geq 30^\circ$ horizontal), out of bed as well as large, medium, small and sitting transitions were classified. Large transitions were defined as transitions that end up in the body position opposite on the starting position (e.g. from right to left side), medium transitions were classified as transitions that end up in an adjacent posture (e.g. from supine to left side), small transitions were transitions that end up in the same position and sitting transitions were transitions which start or end up in a sitting position. The same classification was used for the activity measurement of the MM. The results of the MM measurement were then compared to the results of the video classification and sensitivity and specificity were calculated [6].

Results

A mean duration of 7.6 $\pm$ 0.9 h per night of video and MM classifications were available for analysis yielding a total analysis duration of 151 h 39 m 04 s. Seven hundred and two different postures were registered on the video from which 24 postures (3.4%) were detected differently by the MM. These results yielded a total degree of sensitivity of 93.9% and specificity 94.9% in detecting postures during the night (for detailed sensitivity and specificity results see Table 1).

In total 682 transitions (394 small, 189 medium, 15 large and 84 sitting transitions) were detected of which 482 were also detected by the MM. The MM detected 70% of the transitions correctly (51.0% small, 97.4% medium, 100% large and 97.6% sitting transitions).

Postures that were detected by the MM but not by video classification were mostly close to the borderline of two body positions (the average deviation to another posture boarder was 7.0 $\pm$ 7.9°). The MM detected 200 transitions which were not detected by the video classification. These were mostly small transitions (193 small, 5 medium, 0 large and 2 sitting transitions). The average size of these transitions was 16.1 $\pm$ 9.3° on the longitudinal axis.

Discussion

Within the recent years activity monitoring in patients with chronic respiratory diseases has gained importance since an improvement in physical activity has become one of the major non-pharmacological therapy targets in these patients [7]. Therefore a high accuracy of activity monitors is

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Table 1 Sensitivity and specificity of the DynaPort MoveMonitor for detecting nocturnal postures in comparison to night-vision video classification in 20 patients with chronic respiratory disorders.

	Side left	Side right	Prone	Supine	OOB	Upright	Total
Total time	29 h 37 m 18 s	59 h 33 m 35 s	0 h 00 m 00 s	60 h 46 m 25 s	1 h 27 m 15 s	0 h 14 m 31 s	151 h 39 m 04 s
Sensitivity	92.15	93.86	0	96.58	94.73	70.92	93.93
Specificity	98.18	98.14	0	88.46	99.88	99.69	94.95
PPV	96.74	97.32	0	86.68	93.39	51.62	92.32
NPV	96.57	89.22	0	98.74	99.92	99.94	95.06
F-score	94.04	94.80	0	90.68	93.61	55.81	92.29

OOB = out of bed, PPV = positive predictive values, NPV = negative predictive values.

essential to assess valid data on daily physical activity. Usually the focus of activity monitoring is limited to the patients' activity during daytime. However, an activity monitor that assesses valid data on nocturnal transitions might also provide valuable information on sleep quality. So far only one study [8] has validated an older version of the MM against polysomnography position sensor and found a high intra-class correlation (r = 0.84) for body posture detection. To our knowledge this is the first nocturnal night-vision video evaluation of an activity monitor with regard to posture detection.

In comparison to the video classification the MM showed a high degree of sensitivity and specificity for detecting different postures during sleep with an accuracy comparable to daytime validity of the MM [9]. Inconsistent classifications between the video analysis and the MM results were related to the reason that these postures were close to the borderline of two body positions and transitions were mostly small. Therefore both conditions could only be hardly seen on the video analysis. The procedure of the night-vision video analysis is surely limiting the validity in detecting small transitions especially since patients were covered by a sheet during the night. However, measuring nocturnal movements might comprise a future potential to evaluate sleep behavior. This procedure might even be conveniently performed at the patients' home. Further studies are needed to evaluate potential correlations between nocturnal movements and sleep quality.

Conclusion

The MM is an activity monitor showing a high degree of sensitivity and specificity to detect different nocturnal postures as well as large and medium sized transitions in patients with chronic respiratory disorders.

Conflict of interest statement

RvL is CEO and JP is an employee of McRoberts, the company that produces the DynaPort MoveMonitor. McRoberts provided the DynaPort MoveMonitor devices that were used in this study to the Schoen Klinik Berchtesgadener Land. McRoberts was not involved in the process of video classification. RG, EP, USK and KK are not related to McRoberts and do not have any conflicts of interest to disclose.

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